ELECTRONIC VISION

Scent-Based color identification for patients with visual disability

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Abstract

Nowadays, human disabilities are very common in all places around the world. However, when one person has a disability affecting one of the senses (e.g., sight, hearing), that person usually increases his/her capabilities with other senses. For instance, people with sight-associated disability normally increase their acuteness in senses like hearing and smell. Taking advantage of this human characteristic, in this paper we propose a prototype to offer patients with sight disability the opportunity to identify a set of colors using small amounts of particular essence.

Key words

Patient, Sight disability, RGB sensor, scent, sense capacity

1. Introduction

Human disabilities are common in all societies. In particular, regarding vision impairment, there are several eye problems and conditions that may affect people, preventing them form seeing clearly (e.g., myopia, hyperopia). People with these kinds of conditions have some problems to lead a normal live, since most of the environments in several places of the world do not consider these limitations. In addition, sight disabilities can lead to discrimination [Disabled, , Vision Disability Information][1], potentially affecting labor activities and opportunities.

Another particular vision-impairment condition is colorblindness. This condition affects one in twelve men, and one in two hundred women [2]. There are many types and degrees

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of colorblindness. Monochromasy is the most common type of impairment associated to colorblindness; it consists in people being unable to see colors. On the other hand, Protanomaly refers to a limited ability to see the red color, and people with this disease see red colors as though they were green. Deuteranomaly is also referred to as the weakness to see the green color, and the person has difficulty in telling the difference between red, orange, yellow and green regions of the color spectrum [3].

In this paper, we propose a strategy and further develop a prototype to provide sight-impaired patients with the ability to identify colors using their sense of smell. Initially, the prototype offers this functionality for RGB (i.e. Red, Green, and Blue) colors; however, the strategy can be easily scalable to several basic colors. The prototype is based on the processing of one square signal provided by one RGB sensor. The sensor varies the frequency depending on the scanned color. Based on the processing results made over the sensor signal, one smell is to be spread out. The smell corresponds to one color that can be red, green, or blue.

This paper is structured as follows. Section 2 presents the proposed strategy and the methodology that is used to create a design for the prototype. Section 3 presents the prototype's development, intended for the strategy presented in the previous section. Section 4 presents an evaluation of the prototype based on experimentation conducted over several children with sight disabilities. Finally, section 5 presents the conclusions and the suggested future work.

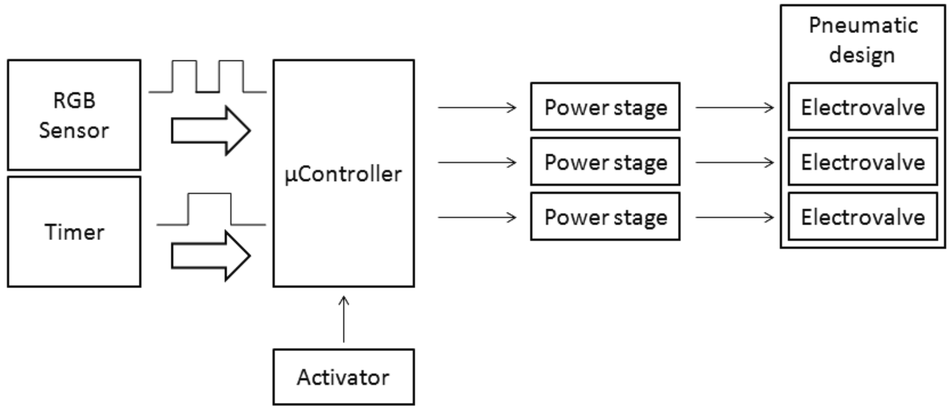
2. Solution Strategy and Methodology

Taking advantage of the superior capacity in smell sense of people with sight disabilities, the proposed strategy consists in implementing a device that can scan colors through an optical sensor. The optical sensor generates an electronic square signal, depending on one scanned color, which can be processed (i.e. red, green, or blue). Based on the processing of the sensor signal through a microcontroller, the device activates one electro-valve (out of three), spreading out a little portion of liquid with a specific smell essence corresponding to the color scanned. The patient can activate the device through an external activator in order to perform the scanning process. Consequently, the patient can activate the device as many times as required.

The scanned signal consists of a square signal with a frequency that can vary form 100 Hz to 220 Hz (These frequencies are obtained based on a specific configuration presented in section 3.1). Thus, in order to process the square signal, it is necessary to calculate its frequency because the value of the frequency determines the scanned color. To calculate this frequency, another signal with a known low-frequency value is used. This known signal should be a square signal as well. In this project, one timer provides the square signal with the known frequency.

On the other hand, electro-valves use a different voltage level than that of all other electronic devices (e.g., timer, microcontroller, and sensor); consequently, it is necessary to use a power stage that can receive one event from the microcontroller for each smell (i.e. one high level corresponding to 5 VDC) and convert it into a higher required voltage level (for the chosen electro-valve, the higher level is 12 VDC) to activate the correspondent electrovalve. Figure 1 presents a diagram with the proposed solution strategy.

Figure 1. Proposed solution strategy



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3. Prototype Development

3.1. Color Sensor

Because the prototype has been designed to identify RGB colors, the TCS3200 color sensor was used (See Figure 2). This sensor works with a power supply of 2.7V to 5.5V and captures light through silicon photodiodes to convert it into an electronic signal, using a single monolithic CMOS integrated circuit. The circuit's output is a square wave with a 50% duty cycle and a frequency value that is proportional to light intensity [4].

Figure 2. TCS3200 color sensor

Source: http://www.abra-electronics.com/products/SEN0101-TCS3200-Color-Sensor.html

The sensor is configurable according to two criteria: 1) output frequency scaling that allows frequency scales of 2%, 20%, or 100% through inputs S_0 and S_1 (see Table 1 and 2) photodiode type that offers filters of red, green, blue, or no filter through inputs S_0 and S_1 (see Table 2).

Table 1. Output frequency scaling options

S_0	S_1	Output
L	L	Power down
L	H	2%
H	L	20%
H	H	100%

Source: own elaboration

Table 2. Filtering options

S_2	S_3	Type
L	L	Red
L	H	Blue
H	L	No filter
H	H	Green

Source: own elaboration

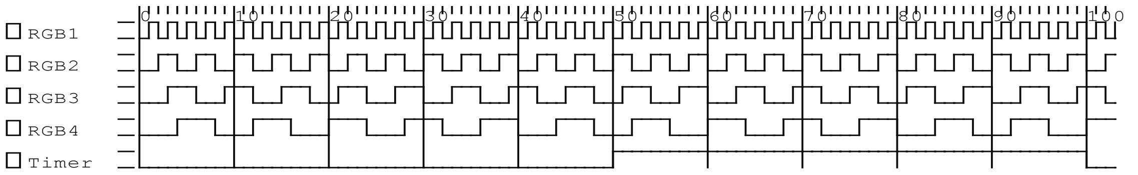
The selected frequency scaling was 2% in order to obtain frequencies from 100 Hz to 220 Hz; thus, these frequencies can be processed with an 8 bit microcontroller. In addition, for each color, the sensor provides a range of frequencies; then, the microcontroller can identify each color using a range of 8 bits. The ranges areas follows: 1) 100Hz to 140Hz corresponds to red, 2) 141Hz to 180Hz corresponds to green, and 3) 180Hz to 20Hz corresponds to blue. Moreover, the filtering option selected in the sensor was *No filter* because all three colors are allowed.

3.2. Timer

In order to calculate the frequency provided by the color sensor, we used another square signal and established its frequency at 1 Hz (i.e. the known frequency is 1 Hz). In order to achieve this frequency, a 555 timer was used [5, 6]. This timer was configured with a 50% duty cycle. Thus, based on the signal of this timer, the frequency of the sensor output signal is calculated by counting the rising edges while the square signal with the known frequency is in high level.

Figure 3 presents an example for calculating the frequency. In this example, the known signal frequency (Timer) is 1 Hz, so the period is 1s and the time during which the signal shows a high level is 0.5 s.

Figure 3. Frequency counting example



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In Figure 3, in signal RGB1, the number of rising edges, while the timer is at high level, is 25. Consequently, in this example, since the timer signal period is 1 second, then the RGB1 signal period is 0.04 s, and the frequency is 25 Hz. Similarly, the frequency of signal RGB2 is 9 Hz, the frequency of signal RGB3 is 5 Hz, and the frequency of signal RGB4 is 7 Hz.

With this technique, there is a high tolerance with low frequencies (i.e. frequencies lower that 30 Hz); consequently, the frequencies in the previous example might not be exact. However, this tolerance is significantly reduced at higher frequencies. The sensor frequencies are over 100 Hz, and up to 220 Hz; and a range of frequencies can identify one color; then, the technique is useful for this project.

In order to configure the timer to get 1 Hz of frequency with 50% duty cycle, the following formulas were applied, equations (1) and (2). In this case, R1 must be equal to R2; so R1 = R2 = 7.2KΩ, and the capacitor is C1 = 100 μF.

$$
\begin{aligned}
Duty\_Cycle &= \left(\frac{R_1}{R_1+R_2}\right)100\% \\
Duty\_Cycle &= \left(\frac{7.2x10^3}{7.2x10^3+7.2x10^3}\right)100\% \qquad (1) \\
Duty\_Cycle &= 50\%
\end{aligned}
$$

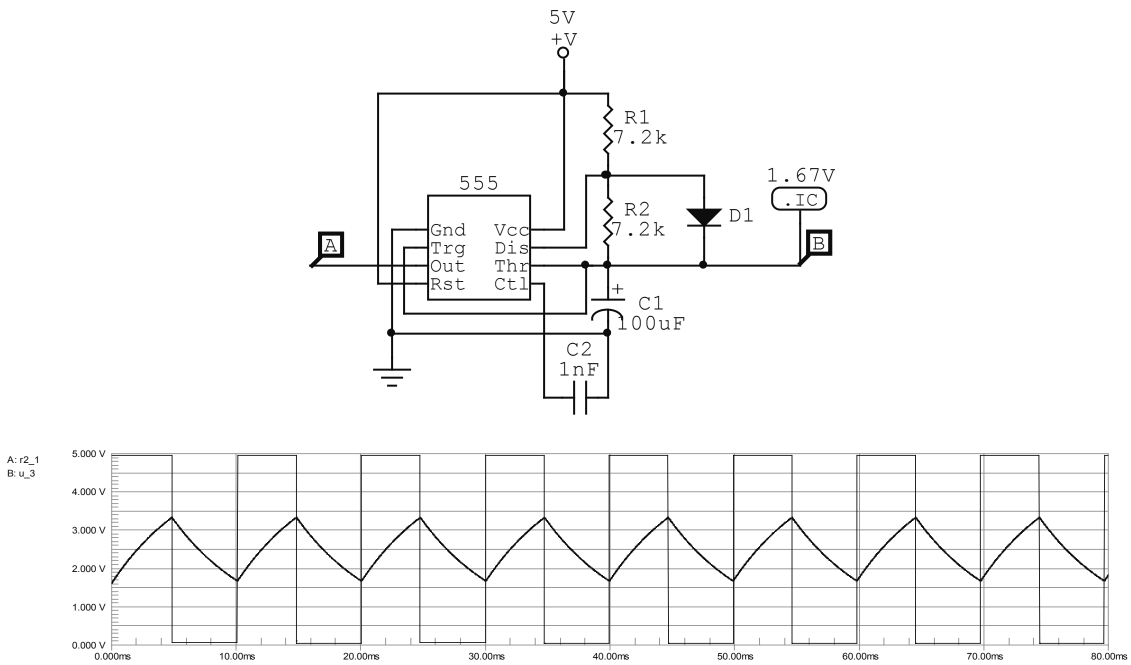
$$f = \frac{1.44}{(R_1 + R_2)C_1}$$

$$f = \frac{1.44}{(7.2x10^3 + 7.2x10^3)x100x10^{-6}} \qquad (2)$$

$$f = 1Hz$$

Figure 4 presents the design for the timer with the corresponding waveform. In order to plot the behavior of C1, initial conditions for the condenser have been set to 1.67 V, which corresponds to the third part of 5V [6, 7].

Figure 4. Schematic and waveform of timer 555, 1 KHz and 50% duty cycle



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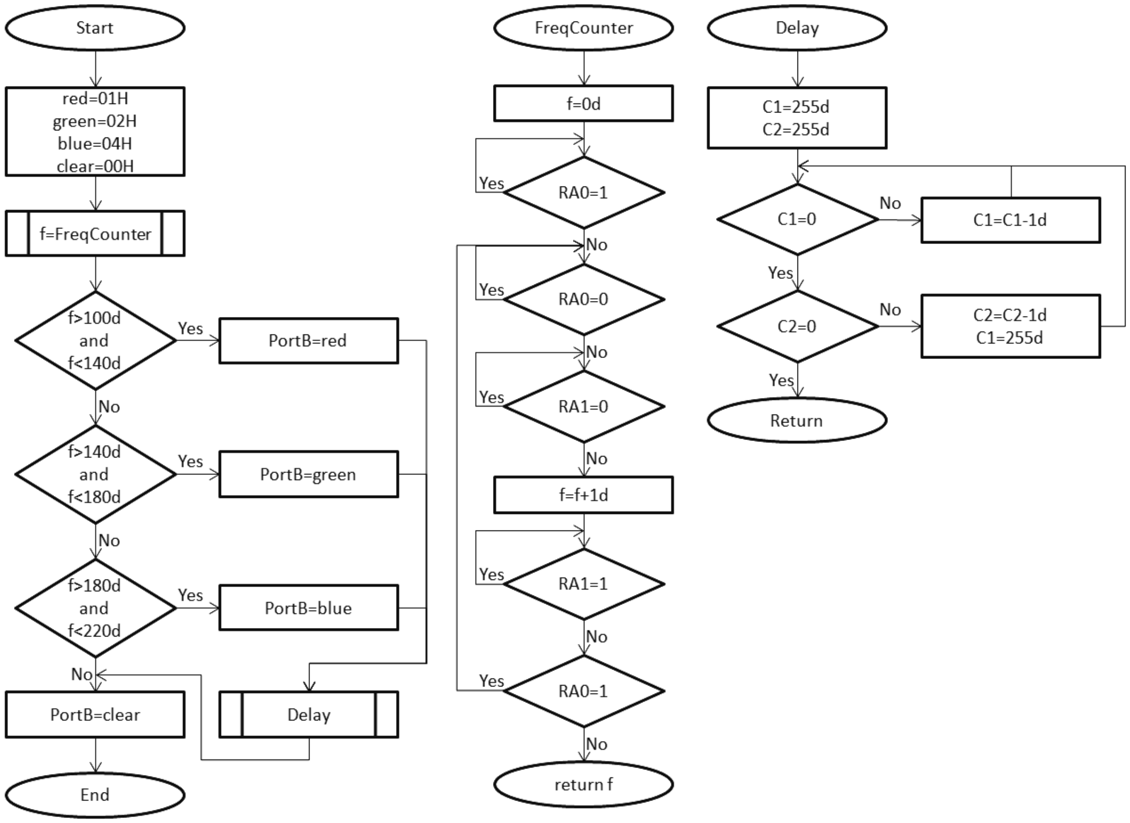
3.3. Microcontroller

The microcontroller used is the PIC 16F84 [8]. This microcontroller has two ports. Port A uses 5 bits and Port B uses 8 bits. For this project, Port A has been configured as the input and Port B as the output. The two Less Significant Bits (LSB) of Port A, called RA0 and RA1, have been used to receive the timer's signal and the sensor's signal, respectively. On the other hand, the three LSBs of Port B; called RB0, RB1, and RB2; have been used to activate the electro-valves through the power stage. Moreover, the microcontroller has been configured using a 4 MHz XT oscillator.

The firmware of the microcontroller allows calculating the sensor frequency and also activates one of the three possible power stages to spread out the corresponding smell. Figure 5 presents the flow diagram of the firmware.

Figure 5. Flow Diagram of the microcontroller firmware



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The firmware calculates the frequency of the signal, provided by the color sensor, using the 1 Hz square signal provided by the timer, also provides the activation of one output bit of the Port B, as its output, to spread out the corresponding smell. This process can be summarized in the following steps:

1. Set, in the variables, the corresponding output values to activate the smells based on the color scanned by the sensor.

2. Calculate the frequency provided by the sensor. This operation consists in the verification of the timer signal until it shows a rising edge. Once it is found, the rising edge of the sensor signal is identified as well, and once it is identified, the variable frequency of the sensor signal is increased. The process is repeated until a falling edge of the timer signal is found.

3. Verify frequency value of the sensor signal in order to set the corresponding data into the output

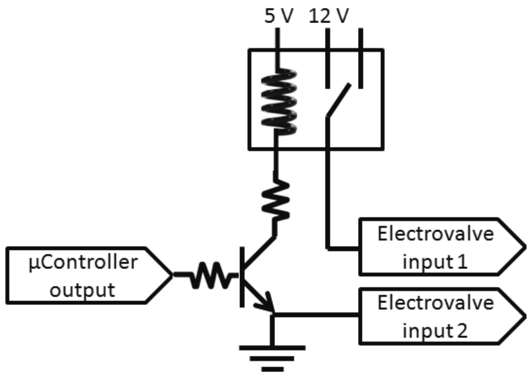
4. Delay the processor by about 400 ms in order to spread out the smell just for an instant of time, long enough to be smelled by the patient.

5. Set a 00H in the output in order to stop the spread.

3.4. Power Stage

The power stage is necessary in this project since the microcontroller offers a digital signal at the outputs with maximum amplitude of 5 VDC (i.e. the high level) with low current; however, the electro-valve works with 12 VDC. The power-stage design is based on three electromagnetic relays. These kinds of relays allow the activation of one internal inductor, which produces a magnetic field, allowing the mechanical activation of two terminals that can bear up to 24 VDC at 2A. As a result, this power stage allows converting 5 VDC, provided by the microcontroller, into 12VDC, required by the electro-valve. Figure 6 presents the power stage design used.

Figure 6. Power stage



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3.5. Pneumatic Design

The pneumatic design contains one air bottle that can be filled with a compressor or a manual air pump. This bottle has a one-way valve to be filled; so, through this valve the compressor or pump can be connected. The bottle is also connected to three electro-valves (i.e. one per smell), and each electrovalve is connected to a small jar that contains liquid with the selected smells for each RGB color. In particular, in this project, the smells used were: strawberry for red, mint for green, and cranberry for blue. Each electro-valve is activated by the microcontroller through the power stage presented in previous sections. Figures 7 and 8 present a 3D model of the pneumatic design.

Figure 7. Pneumatic design front view

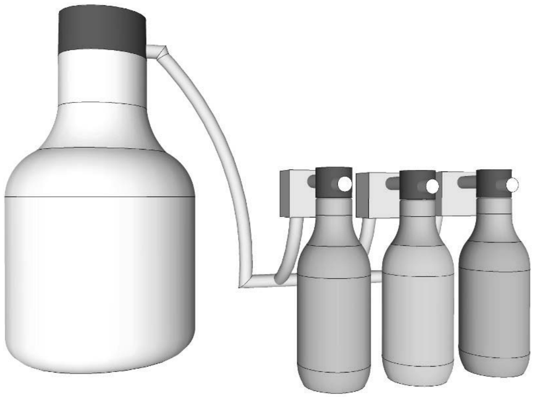

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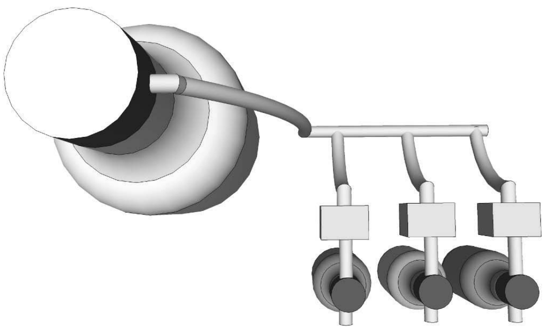
Figure 8. Pneumatic design, view from above



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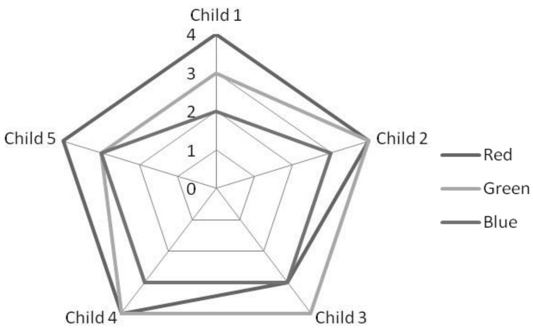
4. Evaluation

The prototype has been evaluated with the cooperation of five children with sight disability. The participants previously knew the relations between colors and their corresponding smells. As previously mentioned, the smells used were the following: strawberry for red, mint for green, and cranberry for blue.

The evaluation consisted of twelve tests performed on each child. One test is just the scanning of one color that must be red, green, or blue (colors were scanned randomly); and the spreading out of the corresponding smell. Each color was scanned four times per children. Children had to determine the color being scanned. Figure 9 presents the results of the evaluation.

Figure 9. Prototype evaluation results



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Based on the results, the most stable color was red, since it was recognized 19 times in 20 attempts. The color green was recognized 18 times in 20 attempts. Finally, the color blue was recognized 14 times in 20 attempts. It seems plausible to claim that the lower level of identification for the color blue is caused by the corresponding smell (cranberry), since such an smell is less usual than the other smells associated to red and green.

5. Conclusions and Future Work

Color recognition in sight disability patients is possible by taking advantage of other human senses such as the sense of smell. This is because patients with this kind of visual conditions normally develop the other senses much better than the average person that has no sight disabilities at all.

The design and prototype presented in this paper have been properly assessed through experimentation. However, although the complete device makes use of a few elements, the size of the device is not appropriate to be carried out by one patient. The reduced number of elements used in the prototype offers the possibility to reduce the size of the final device, using the same elements with smaller integrated circuit encapsulation.

The evaluation has been performed with children that previously knew the smells of the basic colors (e.g. smells for red, green, blue, yellow, purple, etc). Although children did not know that the device provides just three smells, the results show that in almost all cases they identified the correct color.

The device provides three-color recognition. However, the making of a sensor with higher capacity, in terms of color scanning, is possible. The device may be easily scaled in order to offer up to eight-color recognition. Then, as future work, the next step of this proposal is to upgrade the device by changing the sensor, achieving an updated version of the firmware capable of adding other five new smells.

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